

IOWA STATE UNIVERSITY

Digital Repository

Iowa State University Summer Symposium on
Science Communication

2012: Between Scientists & Citizens

Jan 1st, 12:00 AM

The Problem of Communicating Beyond Human Scale

Michael Dahlstrom

Iowa State University, mfd@iastate.edu

Raeann Ritland

Iowa State University, raeanr@iastate.edu

Follow this and additional works at: <https://lib.dr.iastate.edu/sciencecommunication>



Part of the [Other Rhetoric and Composition Commons](#), [Rhetoric Commons](#), and the [Speech and Rhetorical Studies Commons](#)

Dahlstrom, Michael and Ritland, Raeann (2012). The Problem of Communicating Beyond Human Scale. Jean Goodwin (Ed.), *Between Scientists & Citizens*. <https://doi.org/10.31274/sciencecommunication-180809-62>

This Event is brought to you for free and open access by the Conferences and Symposia at Iowa State University Digital Repository. It has been accepted for inclusion in Iowa State University Summer Symposium on Science Communication by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

The Problem of Communicating Beyond Human Scale

MICHAEL DAHLSTROM

*Greenlee School of Journalism and Communication
Iowa State University
215 Hamilton Hall
USA
mfd@iastate.edu*

RAEANN RITLAND

*Greenlee School of Journalism and Communication
Iowa State University
101 Hamilton Hall
USA
raeanr@iastate.edu*

ABSTRACT: Human beings can only experience a thin ribbon of reality constrained by the biological limits of our perceptual systems. Yet, science routinely examines processes and phenomenon outside of human scale and science-related policy requires us to use our conceptions of these toward informed policy making. It often falls to experts to assist non-experts in constructing conceptions beyond human scale. This paper will organize relevant literature from varied fields to introduce the cognitive challenge of comprehending concepts beyond human scale and to suggest what communication techniques experts may find useful to help non-experts arrive at a perception more closely aligned with reality.

KEYWORDS: construal theory, grounded cognition, narrative, numeracy, psychology, psychophysics, risk communication, science communication, visual communication.

1. INTRODUCTION

Human beings can only experience a thin ribbon of reality constrained by the biological limits of our perceptual systems. While we can conceive of varied timeframes, sizes and dimensions, we cannot perceive them directly. Our conceptions of reality beyond human scale are therefore dependent upon the language used to describe it and will be built on analogues from our direct experience, both of which make an accurate conception of such reality unlikely.

Science routinely examines processes and phenomenon outside of human scale and science-related policy routinely asks us to assess our likely inaccurate conceptions of these processes and phenomenon toward informed policy making. While experts have the same perceptual limits as all humans, they often have a much richer conception of such constructs due to their training and experience that enables them to identify patterns that are not perceivable by non-experts (Ericsson & Charness, 1994; Ross, 2006). Therefore, it often falls to experts to explain these processes and phenomenon toward assisting the construction of non-expert perceptions. Since many political decisions depend on these non-expert perceptions, the expert communication of processes and phenomenon beyond human scale becomes crucial for informed decision making.

To take an example, in 2010 the Deepwater Horizon oil spill expelled 4.9 million barrels of crude oil into the Gulf of Mexico (Restore the Gulf, 2010). To arrive at some conception of this magnitude, an individual must take something about which they have direct experience—something within human scale—and perceptually extrapolate to the desired magnitude outside of human scale. In this case, how does an individual extrapolate what they know about liquid volume, possibly thinking of a gallon of milk or the water-filled safety barrels surrounding highway onramps, to construct a perception of 4.9 million barrels? Whatever perception is formed will then determine the perceived severity of the event and opinions about what should be done. For some individuals, 4.9 million may be so meaningless that the risk is never cognitively engaged. To others, 4.9 million may fall within a categorically “large” conception similar to any other value considered “large,” even if the actual values differ by many factors of magnitude. Either perception would likely result in different “appropriate” responses, neither of which may necessarily approach the best action to address the actual magnitude of effect.

Therefore, the primary questions of interest become (1) how do individuals extrapolate information taken from their direct experience in an attempt to comprehend processes and phenomenon beyond human scale and (2) how can experts best use communication to either assist or counter this extrapolation to arrive at a perception more closely aligned with reality? Unfortunately, the cognitive challenges of perceiving beyond human scale remain understudied. No single research area examines these questions. Rather, multiple strands of tangential research occasionally intersect within this scope of inquiry. Therefore, this paper will not attempt to answer these questions, but rather to define the scope of the problem by organizing relevant literature from varied fields linking perceptual limits and psychological extrapolation and suggesting research into communication techniques that may assist experts in improving the accuracy of non-expert conceptions beyond human scale.

2. DEFINING THE PROBLEM

2.1 Psychophysics

The field of psychophysics examines the relationship between physical stimuli and the sensations they produce (Snook, 1999) and attempts to develop mathematical functions that describe these relationships. These functions allow the calculation of the amount of sensory input needed to register a certain psychological perception at a certain magnitude.

One of the most cited of these functions is Weber’s law, named after one of the founders of the discipline, Ernst Heinrich Weber. Weber’s law states that as the magnitude of sensory input increases, it takes a greater increase in sensory input to cause the same increase in perceptions of that sensory input (Solomon, 2009). For instance, it would be easier to notice a difference between objects weighing 10 and 20 pounds than a difference between objects weighing 110 and 120 pounds. The term “Just Noticeable Differences” are used to describe such a unit change in perception (Bartoshuk, 2004; Moskowitz, 2003).

Psychophysics in general, and Weber’s law in particular, can serve as a testable model for our first question of interest. Specifically, Weber’s law provides a function predicting how perceptions can be extrapolated across different magnitudes of sensory input. Our analogous question seeks to develop a function describing how perceptions can be extrapolated across different magnitudes of imagined sensory input. Because it seems reasonable that imagining

the difference between a 10 and 20 pound object is easier than imagining the difference between a 110 and 120 pound object, it is possible that this mental extrapolation of perceptions to different magnitudes may also follow Weber's law.

Current trends in psychophysics research do not address this possibility, instead applying the concept to enhance product development (Moskowitz, 2003) or in the context of visual processing (Murray, 2011). More relevant to our questions concerning human scale is the work of Bartoshuk (2004) who seeks to create a scale that equates people's perceptions across subjects. For example, people can understand the statement, "It was a large mouse that run up the trunk of a small elephant" (Bartoshuk, 2004, p. 17), but it is only after applying the terms within the context of the sentence that people know exactly what "large" and "small" mean. Considering this, Bartoshuk raises the question, "Are individual differences in experience similar? The 'Strongest pain experienced' will obviously denote a more intense pain to a woman who has experienced a particularly painful childbirth than to someone whose most intense pain to date is a stubbed toe" (2004, p. 17). Likewise, "We can compare very weak and very strong rose odors and we can compare very weak and very strong pains, but a very strong pain will be much stronger than a very strong rose odor for most individuals" (Bartoshuk, 2004, p. 17). More research is needed to understand this variability in perceptions based on previous experience and how to best standardize perceptual differences across topics.

2.2 Numerosity and Numeracy

An obvious factor underlying differences in perceived magnitude is that of how individuals perceive numbers. Numerosity refers to how individuals judge how numerous something is, or "how many." Researchers often employ spatial reasoning tasks, done over very short periods of time, involving visual tests of different groupings, arrangements and "connections" of dots (Allik & Tuulmets, 1991; Anobile, Turi, & Burr, 2010; Franconeri, Bemis, & Alvarez, 2009; Frith & Frith, 1972; Gordon, 2004; He, Zhang, Zhou, & Chen, 2009). For instance, a researcher may show two pictures for a split second, each containing varied dot patterns, one with lines connecting dots and one without, and then ask which picture contained more dots.

Results indicate that people use different cognitive processes in number estimation depending on the size of what is to be counted (Anobile et al., 2010; Dehaene & Changeux, 1993; Trick & Pylyshyn, 1994). When faced with small numbers of objects, individuals use subitizing, which is an automatic and accurate process based on visual recognition, for instance noting the difference between two and three coins at a glance. For larger numbers, such as if a coin jar spilled, individuals must resort to counting, an effortful and more inaccurate process (Anobile et al., 2010; Trick & Pylyshyn, 1994). Results also find that people group objects and estimate amounts according to proximity and similarity, but often increase errors with doing so (Allik & Tuulmets, 1991; Frith & Frith, 1972; He et al., 2009). For instance, when objects are clustered, people tend to underestimate their numbers because clustered objects take up less space and appear less numerous. Conversely, when objects are far apart, people tend to overestimate their numbers (Franconeri et al., 2009; He et al., 2009).

Such number estimating techniques may also be culturally dependent. In America, people perceive numbers between 1 and 10 as linear, but logarithmically for larger numbers (Dehaene, Izard, Spelke, & Pica, 2008) whereas an indigenous Amazonian community showed logarithmic perceptions across all values. Likewise, Gordon (2004) found the indigenous Amazonian community follows a "one, two, many" counting system where the individuals

could not accurately represent exact quantities for medium-sized values, such as four or five (Gordon, 2004). When asked to perform matching exercises, the individuals successfully matched groups 0–3, success dropped to a near 0% for numbers 3–6 and then returned to near perfect for groups of 7–10. Gordon (2004) suggests this is perhaps due to chunking, grouping into smaller, more manageable, groups of 2–3.

Numeracy differs from numerosity in that it refers to the representation of numbers rather than amount of objects. One aspect of numeracy involves individual differences of mathematical capabilities based on experience or innate ability and suggests that larger numbers are often more difficult to understand than smaller numbers. Yet beyond individual differences, numeracy also suggests the representation of numbers can influence perceptions (Dehaene et al., 2008; Garcia-Retamero & Galesic, 2011; Gigerenzer & Edwards, 2003; Reyna & Brainerd, 2008). Identical values presented as a frequency (1 out of 100) versus a probability (1%) resulted in different perceptions with the frequency seen as representing greater risk (Gigerenzer & Edwards, 2003; Reyna & Brainerd, 2008). Likewise, the denominator used to present a fraction also influences perceptions. Using smaller denominators that are closer to “plausible” group sizes in human society ($x / 125$) allow easier risk determinations that are less influenced by message framing than when the denominator represents a larger value beyond normal human group sizes ($x / 100,000$) (Garcia-Retamero & Galesic, 2011; Wang, 1996).

Both numerosity and numeracy suggest that how the mind estimates general amounts and comprehends specific number representations can influence changing magnitudes of concepts and may play a role in generating perceptions beyond human scale.

2.3 Grounded Cognition

Grounded cognition is a field of psychology that claims that functions of the mind are limited by biology and heavily influenced by our physical bodies. Unlike traditional theories of cognition that assume the mind and body to be separate, grounded cognition can help explain why there may be a bias for easier comprehension of concepts at the human scale and more difficult comprehension when asked to go beyond—namely that the mind evolved to account for sensory input that directly led to bodily survival. Involved in this process are affordances, which are relationships between action and perception, or possibilities for interaction (Kaschak & Maner, 2009). Simulations of these affordances “allow us to consider, and have our behavior controlled by, knowledge and goals that are not directly signaled by the current environment” (Kaschak & Maner, 2009, p. 1241). Thus, within the frame of grounded cognition is the belief that thoughts are not words or symbols but visual and motor images that are driven by everyday goals (Pecher, Boot, & Van Dantzig, 2011).

Beyond biological limitations, another aspect of our first question of interest that can be addressed through grounded cognition is that of abstraction. Up until this point, we have defined concepts beyond human scale as being of a different magnitude. Yet, much of science is outside of human scale not because of magnitude, but due to being more intangible or abstract than what can be experienced directly. Abstract transfer within grounded cognition can serve to explain how people use grounding to understand abstract ideas. For example, telling a story is an abstract concept, while handing an object to someone is a concrete action. Yet, studies find that both acts of “giving” are represented by a hand movement away from the body (Pecher et al., 2011). Abstract concepts with an analogous action are therefore easy to “ground” in direct experience. However, concepts that become so abstract that there are no

analogous actions in which to ground the experience may result in a categorically different challenge to create perceptions beyond human scale.

2.4 Construal Theory

Abstraction may not just be specific to the process or phenomenon beyond human scale, but also relative to the individual doing the perceiving. Construal theory states that the perception of an event is dependent upon the psychological distance between the event and the perceiver (Kanten, 2011). Four kinds of psychological distance exist: temporal, spatial, social, and probability (Jia, Hirt, & Karpen, 2009; Trope, Liberman, & Wakslak, 2007). In other words, decisions and judgments depend on how “close” an event is to an individual. If an event is farther away, a person’s construal level is higher, leading to a perception that is more abstract, structured and less detailed. In contrast, an event that is closer would cause a person’s construal level to be lower and lead to one that is more concrete, unstructured and more detailed. Events with a high construal level usually answer the “why” of an event, and low construal thoughts answer the “how” (Garcia, 2011).

Results show that all four forms of psychological distance can affect people’s perceptions of events. For example, temporal distance affects descriptions of life satisfaction. People predicted the near future in concrete terms, involving mixed affect, but they predicted the distant future more abstractly, with more positive affect (Heller, Stephan, Kifer, & Sedikides, 2011). Likewise, even subtle changes in spatial distance can influence the creativity in problem solving (Polman & Emich, 2011), and the extremity of affective evaluations is larger when abstract and smaller when concrete (McCarthy & Skowronski, 2011). Visual and verbal representations have also been found to differ in construal levels. Predictably, text should require higher construal because it is more abstract, whereas photographs, which are concrete representations, should require lower construal. Results support these predictions, finding that responses were faster when the medium fit its construal level—photos of domestic objects and names of foreign objects (Trope et al., 2007).

These results suggest that while the human mind may have physiological limits bounded by scale, individual reference points may also play a role in determining what is processed within or beyond human scale for an individual at a particular point in time.

3. POSSIBLE SOLUTIONS

The previous section aimed to summarize literature that could better define the scope of our problem, specifically the challenges involved when individuals extrapolate information from their direct experience in an attempt to comprehend processes and phenomenon beyond human scale. In this section, we begin to suggest areas where a partial solution may be found, specifically areas of communication research that may provide experts with a practical toolkit to assist non-experts in arriving at a perception more closely aligned with reality. We suggest three fields of research that may hold particular promise: metaphor, narrative and visual communication.

3.1 Metaphor

Metaphors are linguistic devices that link two concepts together through some shared trait to emphasize an aspect of the original concept or make it observable in a new light. The concept of metaphor consists of two distinct positions. The first, termed constructivism, views metaphor as an intrinsic quality of all language and the process by which humans create new knowledge. The second, termed non-constructivism, views metaphor as a literary embellishment that allows for a novel interpretation of reality based on emphasizing certain features of the paired concepts (Baake, 2003). The second position is more relevant to the current study.

Science in particular is known for its reliance on metaphor, not just in communication with the public, but also between scientists at the research development stage to formulate hypotheses and interpret data (Baake, 2003). By linking two concepts, metaphors can offer the non-expert public avenues to understand complex scientific phenomenon in terms of something more familiar. However, scientific metaphors can also backfire when they blur the concept they are trying to clarify or introduce unintended associations, and caution is recommended (Weigmann, 2004).

Metaphors may help experts communicate beyond human scale by both removing the need of potentially confusing values and by substituting something concrete in place of something abstract. Returning to our previous example, the 4.9 million barrels of crude oil released in the Gulf of Mexico could be described using a metaphor of a newly constructed toxic 51st state of the union. Such a metaphor describes the size of the event, associates it geographically and emphasizes what about it demands attention, namely the toxic properties, without needing to extrapolate specific values of any unit.

3.2 Narrative

A narrative, or story, represents a specific and temporally structured form of communication where characters and their desires hold a string of events together through a cause and effect relationship. Narratives are thought to be processed differently than non-narrative communication (Fisher, 1984) and are considered by some to represent the fundamental constituents of human cognition (Schank & Abelson, 1995). Supporting this view is research that finds narrative communication is read twice as fast and remembered twice as easily as non-narrative communication (Graesser, Olde, & Klettke, 2002) and can more easily persuade otherwise resistant audiences (Moyer-Guse & Nabi, 2010).

Processing a narrative essentially involves engaging in a mental simulation of some aspect of reality from a particular human point of view (Oatley, 1999). Narratives are therefore a method of packaging an event into a particular viewpoint of human scale. Narratives may help experts communicate beyond human scale by providing a structure that juxtaposes how something beyond human scale looks within human scale.

Returning again to our previous example, the 4.9 million barrels of crude oil released in the Gulf of Mexico may be better communicated as a story or collection of stories told from the viewpoint of individuals nearby or within the event (for example, a narrative of a fisherman who has lost his livelihood or a regular vacationer who was shocked to see changes in the recreational beach or even a fictional crab struggling to escape the suffocating death of the spreading oil). These narratives could portray the magnitude of the event through a mental

simulation that provides an even richer and more complex interplay of context without the need to extrapolate specific values.

3.3 Visual Communication

While communication is often thought of in spoken or written form, visuals represent an additional form of communication that may offer benefits through pattern recognition. In particular, visual communication has been found to improve comprehension of risks, particularly in health contexts (Ancker, Senathirajah, Kukafka, & Starren, 2006; Garcia-Retamero & Galesic, 2010; Lipkus & Hollands, 1999; Zikmund-Fisher et al., 2008). Different forms of visuals are even recommended depending on the type of comprehension desired: tables are better at communicating verbatim information whereas pictographs are better when the overall gist of the information is more important (Hawley et al., 2008).

However, it is important to avoid “hiding” pieces of information when constructing visuals for the communication of risk. Important information can be lost due to the foreground/background salience effect that states that in graphical situations, people are drawn to foreground information and pay less attention to what is in the background. This can skew the risk perception and lead people to incorrect perceptions, especially when the number of people at risk is emphasized at the expense of all those at risk of harm (Stone et al., 2003).

Again returning to our example, rather than attempt to portray the magnitude of 4.9 million barrels of crude oil in words, a visual comparing the volume of oil released in the Deepwater Horizon oil spill, the amount of oil used daily in the U.S. and the amount of oil necessary to cause damage to certain types of ecosystems could assist in constructing a perception of the magnitude of the event that may align more closely with reality, again without the need to extrapolate values beyond human scale.

4. CONCLUSION

The challenge of communicating beyond human scale is an understudied problem within science communication of which experts are often expected to be able to address. The successful communication of these processes and phenomenon outside of human scale is crucial for informed decision making within a democratic society, yet most experts are not equipped to address these challenges and unfortunately very little theoretical work exists to assist them.

Therefore, the purpose of this article was not to propose a solution but to better define the scope of the problem by summarizing literature than begins to explore the challenges of communicating beyond human scale and identifying areas of communication literature where a partial solution might be found.

Specifically, we suggest that the field of psychophysics offers a testable model in Weber’s law to examine how perceptions are extrapolated across different magnitudes of imagined sensory input. Likewise the areas of numerosity, numeracy, grounded cognition and construal theory offer theories and empirical evidence that suggest perceiving concepts beyond human scale becomes increasingly difficult and likely divorced from reality. We also suggest that the areas of metaphor, narrative and visual communication represent promising areas of communication research that may offer practical methods for experts to better address these challenge when communicating to non-experts. Specifically, metaphor addresses the bias of

magnitudes and abstractness, narrative represents a structure that packages abstract concepts into human scale and visual communication can leverage the comprehension benefits of pattern recognition over language-based description.

With the problem defined and relevant literature identified and summarized, this article represents a call for future research to explore these areas to better understand the boundaries of human cognition on an axis of scale, the processing strategies used to address these boundaries, the inaccuracies or biases inherent in these processing strategies and finally how experts can use communication to help correct for these biases. An additional question not addressed in this paper is that even when the answers to these questions are better understood, it is likely that experts will not be adequately trained in using the successful communication techniques. Therefore, additional research needs to examine the organizational structures that may best equip and reward experts for their ability to assist non-experts in the construction of more accurate perceptions beyond human scale.

REFERENCES

- Allik, J., & Tuulmets, T. (1991). Occupancy model of perceived numerosity. *Perception & Psychophysics*, 49(4), 303–314. doi: 10.3758/bf03205986
- Ancker, J. S., Senathirajah, Y., Kukafka, R., & Starren, J. B. (2006). Design features of graphs in health risk communication: A systematic review. *Journal of the American Medical Informatics Association*, 13(6), 608–618. doi: 10.1197/jamia.M2115
- Anobile, G., Turi, M., & Burr, D. C. (2010). Subitizing but not estimation of numerosity requires attentional resources. *Perception*, 39, 80–80.
- Baake, K. (2003). *Metaphor and knowledge: The challenges of writing science*. New York, NY: State University of New York Press.
- Bartoshuk, L. A. (2004). Psychophysics: a journey from the laboratory to the clinic. *Appetite*, 43(1), 15–18. doi: 10.1016/j.appet.2004.02.005
- Dehaene, S., & Changeux, J. P. (1993). Development of elementary numerical abilities—A neuronal model. *Journal of Cognitive Neuroscience*, 5(4), 390–407. doi: 10.1162/jocn.1993.5.4.390
- Dehaene, S., Izard, V., Spelke, E., & Pica, P. (2008). Log or linear? Distinct intuitions of the number scale in Western and Amazonian Indigene cultures. *Science*, 320(5880), 1217–1220. doi: 10.1126/science.1156540
- Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, 1–23.
- Fisher, W. R. (1984). Narration as a human-communication paradigm: The case of public moral argument. *Communication Monographs*, 51(1), 1–22.
- Franconeri, S. L., Bemis, D. K., & Alvarez, G. A. (2009). Number estimation relies on a set of segmented objects. *Cognition*, 113(1), 1–13. doi: 10.1016/j.cognition.2009.07.002
- Frith, C. D., & Frith, U. (1972). Solitaire illusion—Illusion of numerosity. *Perception & Psychophysics*, 11(6), 409–10. doi: 10.3758/bf03206279
- Garcia, D. (2011). Happy today, happy tomorrow: The (non-)effect of temporal distance on judgments of Life Satisfaction. *Personality and Individual Differences*, 51(8), 1048–1051. doi: 10.1016/j.paid.2011.07.031
- Garcia-Retamero, R., & Galesic, M. (2010). Who profits from visual aids: Overcoming challenges in people's understanding of risks. *Social Science & Medicine*, 70(7), 1019–1025. doi: 10.1016/j.socscimed.2009.11.031
- Garcia-Retamero, R., & Galesic, M. (2011). Using plausible group sizes to communicate information about medical risks. *Patient Education and Counseling*, 84(2), 245–250. doi: 10.1016/j.pec.2010.07.027
- Gigerenzer, G., & Edwards, A. (2003). Simple tools for understanding risks: From innumeracy to insight. *British Medical Journal*, 327(7417), 741–744. doi: 10.1136/bmj.327.7417.741

- Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science*, 306(5695), 496–499. doi: 10.1126/science.1094492
- Graesser, A. C., Olde, B., & Klettke, B. (2002). How does the mind construct and represent stories? In M. C. Green, J. J. Strange & T. C. Brock (Eds.), *Narrative impact: Social and cognitive foundations* (pp. 229–262). Mahwah, NJ: Lawrence Erlbaum.
- Hawley, S. T., Zikmund-Fisher, B., Ubel, P., Jancovic, A., Lucas, T., & Fagerlin, A. (2008). The impact of the format of graphical presentation on health-related knowledge and treatment choices. *Patient Education and Counseling*, 73(3), 448–455. doi: 10.1016/j.pec.2008.07.023
- He, L., Zhang, J., Zhou, T., & Chen, L. (2009). Connectedness affects dot numerosity judgment: Implications for configural processing. *Psychonomic Bulletin & Review*, 16(3), 509–517. doi: 10.3758/pbr.16.3.509
- Heller, D., Stephan, E., Kifer, Y., & Sedikides, C. (2011). What will I be? The role of temporal perspective in predictions of affect, traits, and self-narratives. *Journal of Experimental Social Psychology*, 47(3), 610–615. doi: 10.1016/j.jesp.2011.01.010
- Jia, L., Hirt, E. R., & Karpen, S. C. (2009). Lessons from a Faraway land: The effect of spatial distance on creative cognition. *Journal of Experimental Social Psychology*, 45(5), 1127–1131. doi: 10.1016/j.jesp.2009.05.015
- Kanten, A. B. (2011). The effect of construal level on predictions of task duration. *Journal of Experimental Social Psychology*, 47(6), 1037–1047. doi: 10.1016/j.jesp.2011.04.005
- Kaschak, M. P., & Maner, J. K. (2009). Embodiment, evolution, and social cognition: An integrative framework. *European Journal of Social Psychology*, 39(7), 1236–1244. doi: 10.1002/ejsp.664
- Lipkus, I. M., & Hollands, J. G. (1999). The visual communication of risk. *Journal of the National Cancer Institute Monographs*, 1999 (25), 149–163.
- McCarthy, R. J., & Skowronski, J. J. (2011). You're getting warmer: Level of construal affects the impact of central traits on impression formation. *Journal of Experimental Social Psychology*, 47(6), 1304–1307. doi: 10.1016/j.jesp.2011.05.017
- Moskowitz, H. R. (2003). The intertwining of psychophysics and sensory analysis: Historical perspectives and future opportunities—A personal view. *Food Quality and Preference*, 14(2), 87–98. doi: 10.1016/s0950-3293(02)00072-1
- Moyer-Guse, E., & Nabi, R. L. (2010). Explaining the effects of narrative in an entertainment television program: Overcoming resistance to persuasion. *Human Communication Research*, 36(1), 26–52. doi: 10.1111/j.1468-2958.2009.01367.x
- Murray, R. F. (2011). Classification images: A review. *Journal of Vision*, 11(5). doi: 10.1167/11.5.2
- Oatley, K. (1999). Why fiction may be twice as true as fact: Fiction as cognitive and emotional simulation. *Review of General Psychology*, 3(2), 101–117.
- Pecher, D., Boot, I., & Van Dantzig, S. (2011). Abstract concepts: Sensory-motor grounding, metaphors, and beyond. *Psychology of Learning and Motivation: Advances in Research and Theory*, 54, 217–248.
- Polman, E., & Emich, K. J. (2011). Decisions for others are more creative than decisions for the self. *Personality and Social Psychology Bulletin*, 37(4), 492–501. doi: 10.1177/0146167211398362
- Restore the Gulf. (2010). U.S. scientific teams refine estimates of oil flow from BPs well prior to capping. Retrieved from <http://www.restorethegulf.gov/release/2010/08/02/us-scientific-teams-refine-estimates-oil-flow-bps-well-prior-capping>
- Reyna, V. F., & Brainerd, C. J. (2008). Numeracy, ratio bias, and denominator neglect in judgments of risk and probability. *Learning and Individual Differences*, 18(1), 89–107. doi: 10.1016/j.lindif.2007.03.011
- Ross, P. E. (2006). The expert mind. *Scientific American*, 295(2), 64–71.
- Schank, R. C., & Abelson, R. (1995). Knowledge and memory: The real story. In R.S. Wyer, Jr. (Ed.), *Knowledge and memory: The real story* (pp. 1–87). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Snook, S. H. (1999). Future directions of psychophysical studies. *Scandinavian Journal of Work Environment & Health*, 25, 13–18.
- Solomon, J. A. (2009). The history of dipper functions. *Attention Perception & Psychophysics*, 71(3), 435–443. doi: 10.3758/app.71.3.435

- Stone, E. R., Sieck, W. R., Bull, B. E., Yates, J. F., Parks, S. C., & Rush, C. J. (2003). Foreground : Background salience: Explaining the effects of graphical displays on risk avoidance. *Organizational Behavior and Human Decision Processes*, 90(1), 19–36. doi: 10.1016/s0749-5978(03)00003-7
- Trick, L. M., & Pylyshyn, Z. W. (1994). Why are small and large numbers enumerated differently—A limited capacity preattentive stage in vision. *Psychological Review*, 101(1), 80–102. doi: 10.1037//0033-295x.101.1.80
- Trope, Y., Liberman, N., & Wakslak, C. (2007). Construal levels and psychological distance: Effects on representation, prediction, evaluation, and behavior. *Journal of Consumer Psychology*, 17(2), 83–95. doi: 10.1016/s1057-7408(07)70013-x
- Wang, X. T. (1996). Domain-specific rationality in human choices: Violations of utility axioms and social contexts. *Cognition*, 60(1), 31–63. doi: 10.1016/0010-0277(95)00700-8
- Weigmann, K. (2004). The code, the text and the language of God—When explaining science and its implications to the lay public, metaphors come in handy. But their indiscriminate use could also easily backfire. *Embo Reports*, 5(2), 116–118. doi: 10.1038/sj.embor.7400069
- Zikmund-Fisher, B. J., et al. (2008). Communicating side effect risks in a tamoxifen prophylaxis decision aid: The debiasing influence of pictographs. *Patient Education and Counseling*, 73(2), 209–214. doi: 10.1016/j.pec.2008.05.010